Integrated Air Pressure Sensor with Analog Interface — 524.73

PRODUCT PREVIEW – Nov 06, 2017

RoHS compliant

Features

- Fully integrated and compensated pressure sensor
- Different measurement ranges of absolute pressure available
  - Version D432: 15 - 115 kPa with clipping of output voltage
  - Version D433: 60 - 165 kPa with extended output range capability
- Full thermal compensation to accuracy ±1.0 %FS
- Ratiometric analog output
- Wide linear range of analog output
- Two 16-bit ADCs for acquisition of pressure and temperature input data
- Diagnosis of sensor, sensor supply wiring, and NVM CRC check at power-on
- Supply voltage: 5.0V ±0.5V
- Large temperature range -40 ... + 125°C
- Automotive qualified acc. to AEC-Q100

Applications

- Automotive applications, e.g. for manifold air pressure (MAP) or barometric air pressure (BAP)
- Industrial applications
- Medical applications

General Description

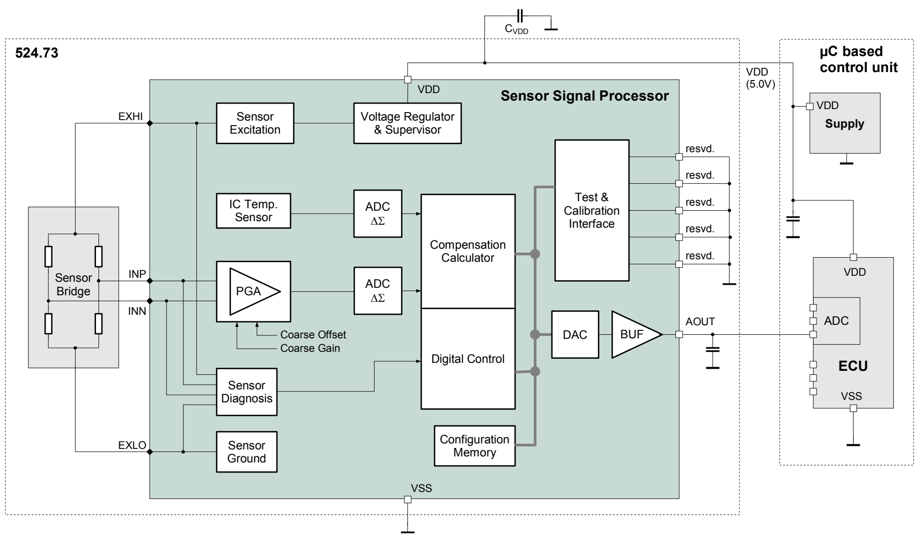
The E524.73 is an integrated absolute pressure sensor for air pressure measurement. It includes a piezo-resistive sensing element and a signal processing IC, which performs amplification and thermal compensation of the sensor bridge voltage to provide a linear, thermally stable signal output.
The sensor delivers calibrated output data at a ratiometric analog voltage output. The pressure range is mapped linearly to the nominal output range.
Additionally, in version D432 an output clipping is implemented which limits the ouput voltage to V_{CL_lo} to V_{CL_hi} in case of pressure exceeding the specific input range.
Sensor specific calibration data, configuration and product ID are stored in an embedded NVM.
The 524.73 sensor device features a SO8n plastic package. Combining high accuracy with a small size leaded package (footprint area 5 x 6 mm) the 524.73 fits very well to many automotive applications such as barometric air pressure (BAP), manifold air pressure (MAP) or specific industrial and medical applications.

Ordering Information

Product ID	***Ordering Code***	***Pressure Range***	***Feature***
E524.73A	E52473A53D432	15 - 115 kPa	Output clipping
E524.73A	E52473A53D433	65 - 165 kPa	Extended output range

* for package details including pressure interfacing see Figure 8-1

Typical Operating Circuit



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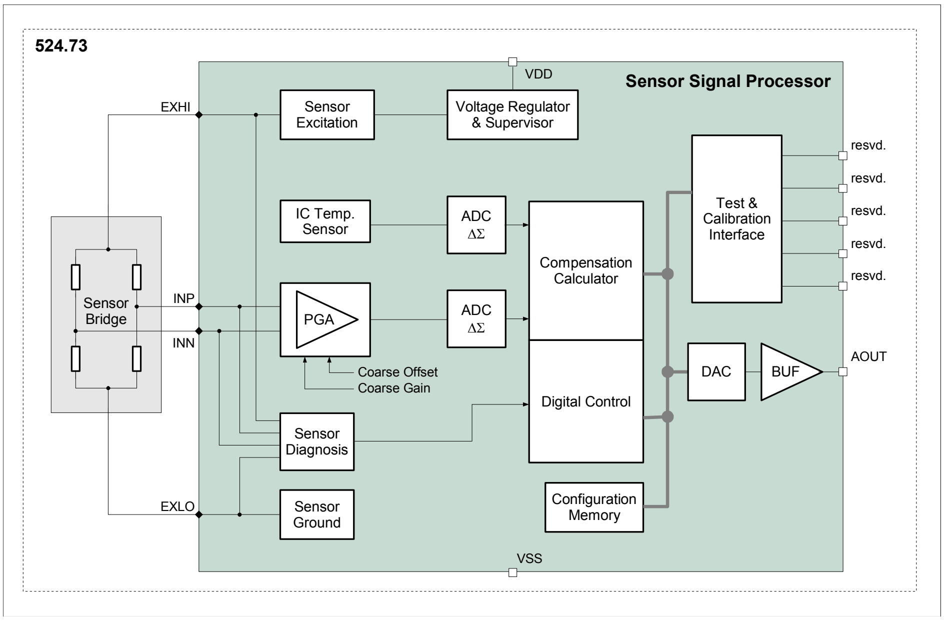
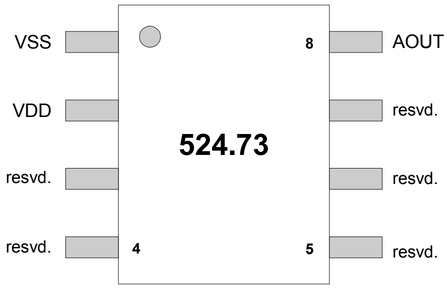
Functional Diagram



Pin Configuration



Pin Description

No.	Name	Type	Description
1	VSS	S	Ground (Negative device supply)
2	VDD	S	Supply voltage
3	resvd.	D_I	reserved [1)]
4	resvd.	D_I	reserved [1)]
5	resvd.	D_I	reserved [1)]
6	resvd.	D_B	reserved [1)]
7	resvd.	D_I	reserved [1)]
8	AOUT	A_O	Analog voltage output (ratiometric)

Note: A = Analog, D = Digital, S = Supply, I = Input, O = Output, B = Bidirectional, NC - not connected

[1)] digital pins used during device test and calibration, only. Recommended to connect to VSS on application board.

1 Absolute Maximum Ratings

Stresses beyond these absolute maximum ratings listed below may cause permanent damage to the device. **These are stress ratings only; operation of the device at these or any other conditions beyond those listed in the operational sections of this document is not implied.** Exposure to absolute maximum rated conditions for extended periods may affect device reliability. All voltages referred to VSS. Currents flowing into terminals are positive, those drawn out of a terminal are negative.

Table 1-1: Absolute Maximum Ratings

No.	Description	Condition	Symbol	Min	Max	Unit
1	Supply Voltage		VDD	-0.3	6	V
2	Analog output voltage		V_{AOUT}	-0.3	VDD+0.3	V
3	Analog output current		I_{AOUT}	-15	15	mA
4	Voltage at test interface pins		$V_{IO,DIG}$	-0.3	VDD+0.3	V
5	Current at test interface pins		$I_{IO,DIG}$	-10	+10	mA
6	Ambient pressure		p_A	1	600	kPa
7	Junction Temperature		T_J	-40	130	°C
8	Storage temperature		T_{STG}	-40	125	°C
9	Power dissipation	$T_A \leq 125°C$	P_{el}		38	mW

2 ESD

Table 2-1: ESD ratings

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	ESD HBM Protection at all Pins	AEC Q100-002 (HBM) chip level test	$V_{ESD(HBM)}$	-2		-2	kV
2	ESD CDM Protection at all Pins	AEC Q100-011 (CDM) chip level test	$V_{ESD(CDM)}$	-500		-500	V
3	ESD CDM Protection at Corner Pins	AEC Q100-011 (CDM) chip level test	$V_{ESD(CDM), C}$	-750		-750	V

3 Recommended Operating Conditions

The recommended operating conditions must not be exceeded in order to ensure proper functionality of the device. All parameters specified in the following sections refer to these recommended operating conditions unless stated otherwise.

Table 3-1: Recommended Operating Conditions

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	Supply Voltage		V_{VDD}	4.5	-	5.5	V
2	Output current at AOUT (DC)	pull-up resistor applied	$I_{AOUT,sink}$	-	-	2.0	mA
3	Output current at AOUT (DC)	pull-down resistor applied	$I_{AOUT,src}$	-2.0	-	-	mA
4	Operating Temperature	ambient	T_A	-40		125	°C
5	Operating Pressure Range - Version D432		$p_{A,\ D432}$	15		115	kPa
6	Operating Pressure Range - Version D433		$p_{A,\ D433}$	60		165	kPa

4 External Components

Table 4-1: External Components

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	Supply bypass capacitor*)		C_{VDD}		100		nF
2	Capacitor load at analog out*)		C_{AOUT}		10		nF

*) Not tested in production

5 Electrical Characteristics

(V_{DD} = 4.5V to 5.5V, T_A=-40°C to + 125°C, unless otherwise noted. Typical values are at V_{DD} = 5.0V and T_A=+25°C. Positive currents flow into the device pins.)

5.1 Sensor Transfer Function Parameters

Table 5.1-1: Version **D432** (15 - 115 kPa)

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	Output Sensitivity	VDD = 5.0V	c432		40		mV/ kPa
2	Accuracy pressure measurement, mid temperature range [1]	T_{MID} = 0 ...85°C, 15...115kPa	$\Delta P_{TMID\ (D432)}$	-1.0		+1.0	kPa
3	Accuracy pressure measurement, low temperature range [1]	T_{LOW} = -40°C, 15...115kPa	$\Delta P_{TLOW\ (D432)}$	-2.0		+2.0	kPa
4	Accuracy pressure measurement, high temperature range [1]1)^^	T_{HIGH} = 125°C, 15...115kPa	$\Delta P_{THIGH\ (D432)}$	-2.0		+2.0	kPa
5	Lower clipping level[*)]		V_{CL_lo}	9.5	10	10.5	% VDD
6	Upper clipping level[*)]		V_{CL_hi}	89.5	90	90.5	% VDD

*) Not tested in production
1) For a graphical description of the tolerance band see Figure 6.2.4-1

Table 5.1-2: Version **D433** (65 - 165 kPa)

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	Output Sensitivity	VDD = 5.0V	c433		43.8		mV/ kPa
2	Accuracy pressure measurement, mid temperature range [1]	T_{MID} = 0 ...85°C, 60...165kPa	$\Delta P_{TMID\ (D433)}$	-1		1	kPa
3	Accuracy pressure measurement, low temperature range [1]	T_{LOW} = -40°C, 60...165kPa	$\Delta P_{TLOW\ (D433)}$	-2		2	kPa
4	Accuracy pressure measurement, high temperature range[1)]	T_{MID} = 125°C, 60...165kPa	$\Delta P_{THIGH\ (D433)}$	-2		2	kPa

1) For a graphical description of the tolerance band see Figure 6.2.4-1

5.2 Voltage Supply

Table 5.2-1: Supply Parameters

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	Current consumption	continuous oper- ation	I_{VDD}	1.0	5.0	7.0	mA
2	Power OK reset threshold VDD, rising edge		$V_{VDD,TH}$	2.1	2.35	2.6	V

5.3 Analog Output

Table 5.3-1: Analog Output Parameters

No.	Description	Condition	Symbol	Min	Typ	Max	Unit
1	Linear output range, upper limit[1)]	$R_{AOUT,PD}$ = 5 kΩ, linearity error < 7.5 mV	$V_{AOUT,UL,5k}$	94	96		%VDD
2	Linear output range, upper limit[1)]	$R_{AOUT,PD}$ = 40 kΩ, linearity error < 7.5 mV	$V_{AOUT,UL,40k}$	97	97.5		%VDD
3	Linear output range, lower limit[1)]	$R_{AOUT,PU}$ = 5 kΩ, linearity error < 7.5 mV	$V_{AOUT,LL,5k}$		4	6	%VDD
4	Linear output range, lower limit[1)]	$R_{AOUT,PU}$ = 40 kΩ, linearity error < 7.5 mV	$V_{AOUT,LL,40k}$		1.5	2	%VDD
5	Analog output source current limit	$V_{AOUT}= V_{SS}$	$I_{AOUT,sourceLIM}$	-20	-16	-12	mA
6	Analog output sink current limit	$V_{AOUT}= V_{DD}$	$I_{AOUT,sinkLIM}$	12	16	20	mA
7	Power-up time[*) 2)]	from VDD > 4.5V to output settled to 90% of final value	t_{UP}			5	ms
8	Step response time[*) 3)]	pressure step response; output rising from 10% to 90% of final value	t_{RESP}			1	ms
9	Step response settling time[*) 3)]	pressure step response; output settling to full accuracy	t_{Settle}			10	ms
10	Output noise[*)]		$v_{o,noise}$		0.3	0.5	mV_{rms}

[*)] Not tested in production
[1)] measured without setting of clipping levels V_{CL_lo} and V_{CL_hi}
[2)] see Figure 6.5-1 for a description in a diagram
[3)] see Figure 6.5-2 for a description in a diagram

6 Functional Description

6.1 Overview

The E524.73 is a high precision, factory calibrated integrated absolute pressure sensor for barometric air pressure measurement. Pressure output data are available at an analog ratiometric voltage output.

6.2 Sensor Transfer Function Parameters

6.2.1 Analog Pressure Transfer Function

At the analog output AOUT the E524.73 sensor provides a calibrated voltage which is following a linear function of output voltage versus absolute pressure. The output voltage is always referenced to the supply VDD, i.e. the output is ratiometric:

$$V_{A,out} = V_{DD} \cdot (c_1 \cdot P_A + c_0)$$

The characteristic parameters gain c_1 and offset c_0 are trimmed during the calibration process.

6.2.2 Transfer function - Variant D432

Table 6.2.2-1: Pressure transfer function parameters

Pressure		***AOUT voltage @ VDD = 5.0 V***		***Sensitivity / Offset***		
Symbol	**Pressure [kPa]**	**Symbol**	**Voltage [V]**	**Symbol**	**Value**	**Unit**
$P_{A,1}$	15	$V_{AOUT,1}$	0.5	c_1	0.80	%VDD/kPa
$P_{A,2}$	115	$V_{AOUT,2}$	4.5	c_0	-2.0	%VDD

The transfer characteristic is depicted in the diagram below (Figure 6.2.2-1). The analog output shall be clipped as pressure input exceeds the lower and higher pressure limits at the output clipping levels V_{CL_lo} and V_{CL_hi}, respect-ively, which are defined by the digital limitation values of the DAC.
In case of an internal error detected by the integrated diagnosis circuitry, the error will be indicated by pulling the analog output AOUT to 0V (VSS) with maximum drive capability of the output.

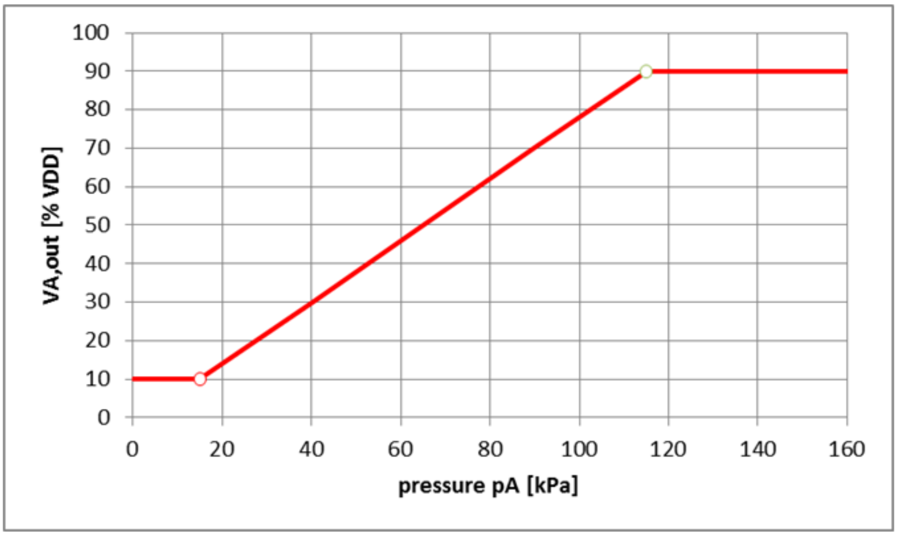


Figure 6.2.2-1: Pressure Transfer Characteristic (15 - 115 kPa)

6.2.3 Transfer function - Variant D433

Table 6.2.3-1: Pressure transfer function parameters

Pressure		***AOUT voltage @ VDD = 5.0 V***		***Sensitivity / Offset***		
Symbol	**Pressure [kPa]**	**Symbol**	**Voltage [V]**	**Symbol**	**Value**	**Unit**
$P_{A,1}$	60	$V_{AOUT,1}$	0.2	c_1	0.876	%VDD/kPa
$P_{A,2}$	165	$V_{AOUT,2}$	4.8	c_0	-48.571	%VDD

The transfer characteristic is depicted in the diagram below (Figure 6.2.3-1.

In case of an internal error detected by the integrated diagnosis circuitry, the error will be indicated by pulling the analog output AOUT to 0V (VSS) with maximum drive capability of the output.

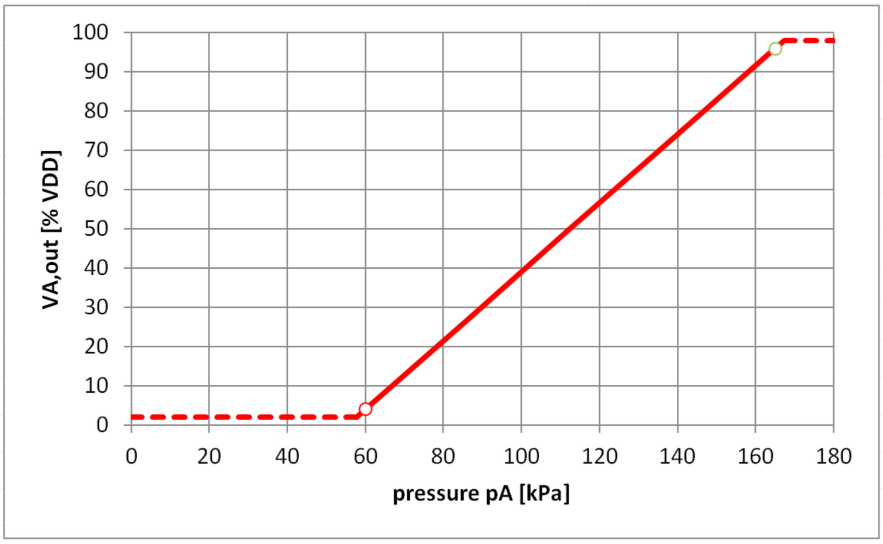


Figure 6.2.3-1: Pressure Transfer Characteristic (60 - 165 kPa)

6.2.4 Pressure accuracy

The accuracy of the measured pressure output is given in medium temperature range TMID = 0 ... 85°C, low temperature range TLOW = -40°C ... 0°C, and high temperature range THIGH = 85°C ... 125°C, respectively. Best accuracy is achieved in the medium temperature range. The accuracy bands are enlarged linearly towards min. and max. temperatures as depicted in Figure 6.2.4-1.

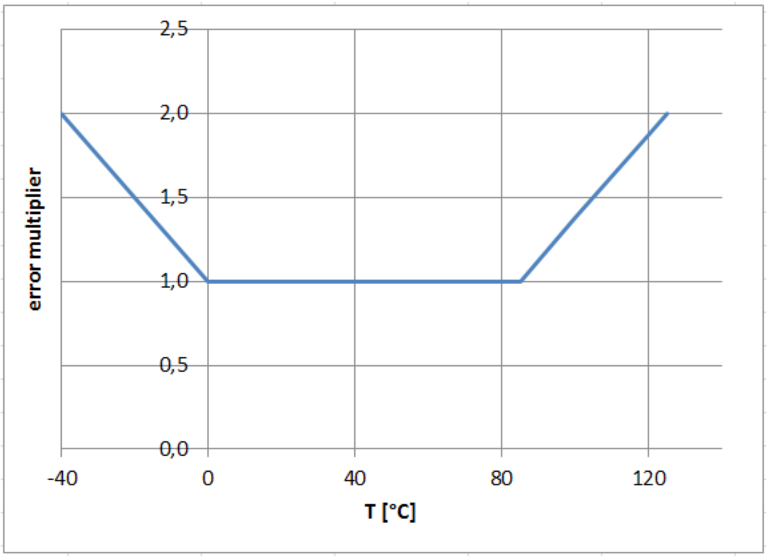


Figure 6.2.4-1: Temperature dependent error multiplier of pressure accuracy

6.3 Voltage Supply

The sensor device is supplied from pin VDD (typical 5.0V). From this supply input several internal voltage regulators are generating stabilized voltage levels for analog and digital circuit sections. The different internal voltage levels are supervised by comparator structures ("power OK check").
Also, a stabilized supply voltage for the internal resistive pressure cell is derived from VDD.

6.4 Pressure Signal Path

The signal from a resistive pressure sensor bridge is processed in the analog front-end (AFE) of the integrated sensor signal conditioner as depicted in Figure 6.4-1.

Here, the differential voltage input is amplified in a two stage programmable gain amplifier (PGA1, PGA2). This allows to optimize the gain setting to the full-scale input from the resistive bridge. Additionally, an offset correction network in the analog front-end (after the first amplifier stage PGA1) supports coarse offset trimming by a voltage injected from a DAC. The output from the 2nd amplifier stage is fed to a high resolution ADC. A digital low-pass filter is used to adjust the response time and overall noise performance of the sensor IC.
The complete signal pre-processing in the analog front-end is fully ratiometric to an on-chip voltage reference, i.e. the bridge supply, offset-DAC and the ADC reference are related to the same reference. Due to this construction, any variations of the reference voltage will be cancelled in the digitized output of the ADC, resulting in negligible temperature variation of the acquired pressured signal and an excellent power supply rejection.

All trimming parameters are adjusted to achieve optimum performance for the resistive sensor bridge used inside this pressure sensor device.

The resistive bridge type pressure sensor cell connected at internal pins SIP, SIN, SVDD, and SVSS, respectively, is supervised by the sensor bridge diagnostic as described in chapter 6.6.1.

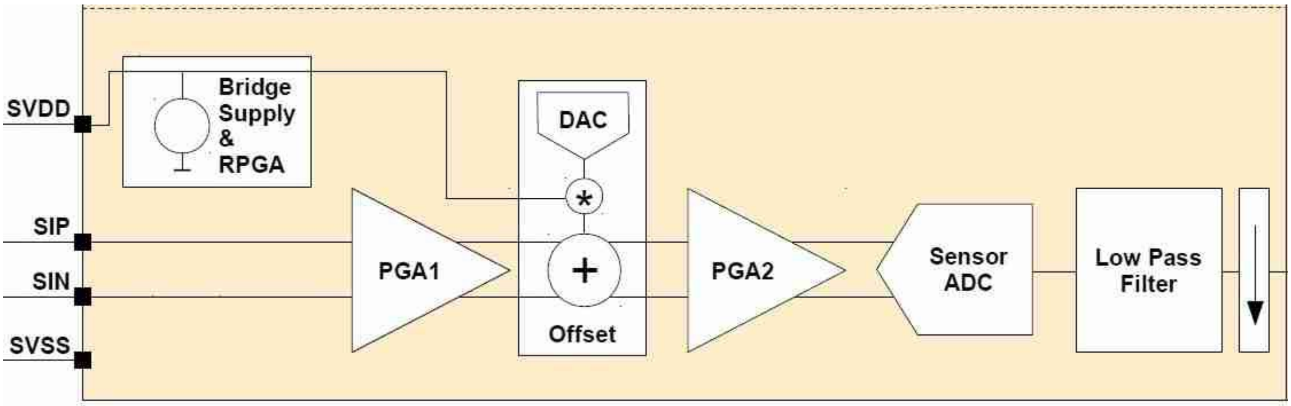


Figure 6.4-1: Pressure Signal Path (AFE)

After digital signal correction, the output data are transferred to a linear DA-converter (DAC), which is driving a linear voltage buffer stage providing the analog output voltage at AOUT (see next section).

6.5 Analog Output

The analog output at AOUT is equipped with a rail-to-rail analog voltage buffer which is driven by a DA-converter. This output is capable to drive the output with high linearity to levels exceeding the clipping limits V_{CL_lo} and V_{CL_hi}, respectively. A current limitation protects the analog output from possible damages caused by shorts to ground or supply.

Power-Up Delay Time

The settling of the pressure output AOUT after power-up is described by the power-up time (delay) as depicted in the following diagram.

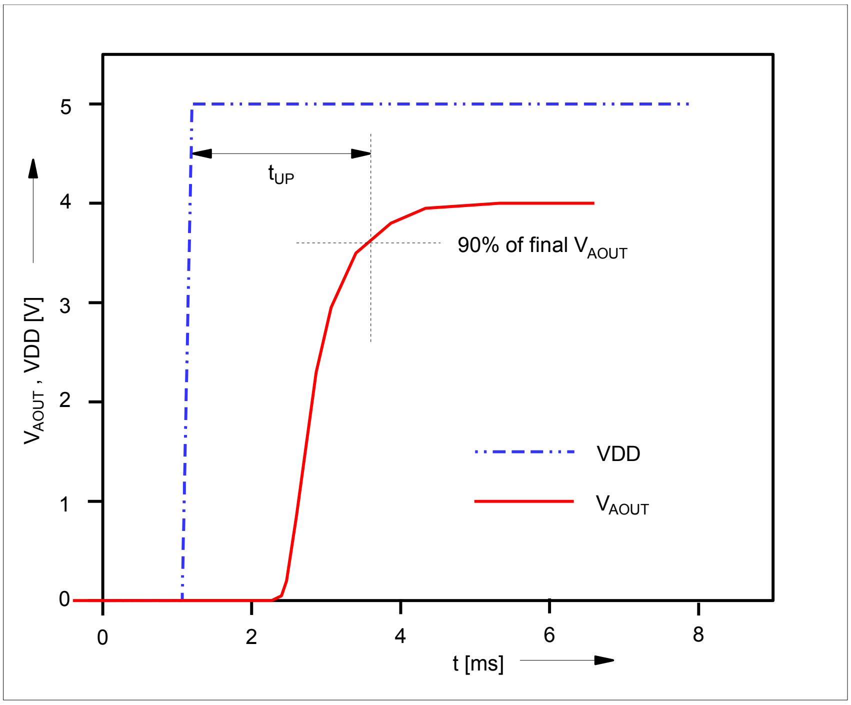


Figure 6.5-1: Power-Up time delay - @ constant pressure

Step Response Timing
The reaction of the output to a step at the pressure input is described by a (basic) response time t_{RESP} which includes both chip internal latency time of the digital sensor signal processor and its characteristic filter response. To characterize the complete settling to the final output value at a given constant pressure, the parameter t_{SETTLE} is introduced. It specifies the time until the output signal is stable to an error band $\pm\ \varepsilon$, where ε describes the specified pressure tolerance ΔP. These parameters are depicted in the following timing diagram.

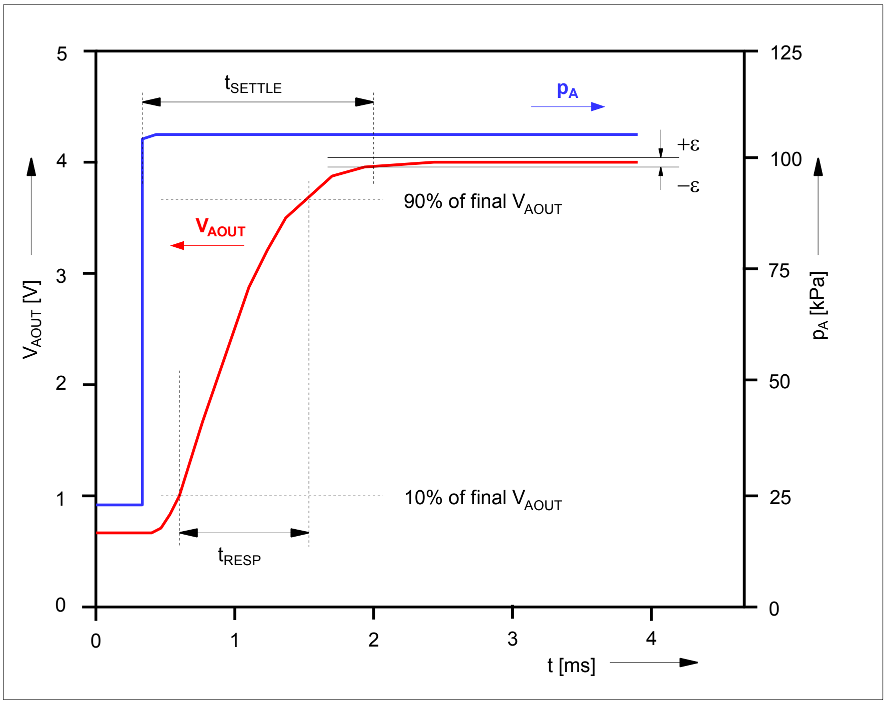


Figure 6.5-2: Step Response Delay

6.6 Diagnosis Functions

6.6.1 Sensor Bridge Diagnostics

Internal errors of the pressure sensor shall be detected and indicated at the signal output AOUT as described in the section **Error Indication** below.

Bridge Diagnostics
An integrated bridge diagnostic circuit supervises the resistive pressure sensor cell to detect any of the faults as follows:

- *Sensor faults*:
  - Short of any of the four bridge resistors of the pressure cell
  - Interruption of any of the four of bridge resistors

- *Wiring faults*:
  - Open connection of any of the bridge supply or signal inputs SVDD, SVSS, SIP, or SIN
  - Wrong connection of any sensor bridge terminal SIP or SIN to either SVDD or SVSS

For bridge diagnostics the signal input path pins SIP and SIN are pulled to ground with two matched low current sinks, which are active permanently (true background diagnostics). The voltage levels of the two signal path inputs

(SIP and SIN) are monitored by two window comparators with detection thresholds of the low and high comparators at 25% SVDD and 75% SVDD, respectively.
The comparator outputs are combined in a logic (OR) and fed to a debouncing low pass filter. In case a *bridge check fail* event an error indicator bit will be set to initiate the error indication at AOUT (s. below).

Bridge Supply Diagnostics
Another comparator function checks if the supply to the sensor bridge is in its specified range. Also, in case of a *bridge supply fail* event an error indicator bit will be set to initiate the error indication at AOUT (s. below).

Error indication
If a bridge diagnosis failure or bridge supply failure occurred, this error will be indicated by pulling the output AOUT to ground level (VSS).

6.6.2 Configuration Memory Check

The integrity of data stored in the embedded NVM used as the configuration memory (calibration parameters, device configuration, device ID, etc.) is checked at power-up of the component by calculation of a check sum (CRC). If a CRC is detected no reliable pressure calculation is possible. Therefore, the sensor remains in idle state, without transferring pressure data to DAC output registers.

Error Indication
If an NVM CRC error occurs, the pin AOUT will remain in high impedance state after power-up. This state can be indicated to a receiver by a pull-down (or pull-up) resistor on the output line, which will force the output of the device out of the regular voltage range limited by the clipping levels V_{CL_lo} to V_{CL_hi}.

7 Typical Applications

A typical application circuit is shown in Figure 7-1. Blocking capacitor to supply VDD is mandatory. Additional capacitor on the analog output line of the sensor should be used for EMI optimization.
If necessary, pull-up or pull-down resistor on the receiver side (ECU) of the line can be used to detect a high-Z state of the output as an indication of diagnosis failures. Additional filter R, C at the ECU-input can be applied to limit the input bandwidth for optimization of disturbances and noise.

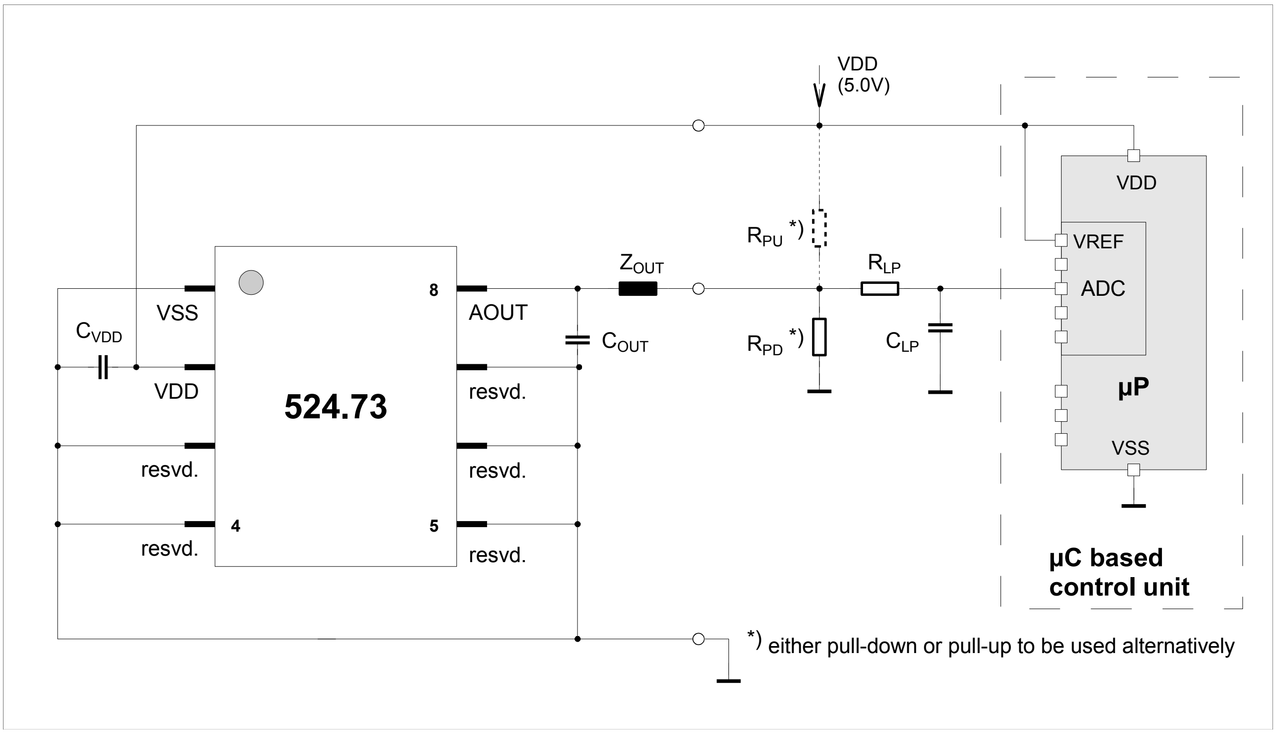


Figure 7-1: Typical Application Example

Table 7-1: Passive component values

Description	Symbol	Min	Typ	Max	Unit
Supply line blocking capacitor	C_{VDD}	47	100	220	nF
Output capacitor	C_{OUT}	-	10	22	nF
Output filter resistor (or ferrite) [1]	Z_{OUT}	0		50	Ω
Output line pull-down [2]	R_{PD}	4	10	-	kΩ
Output line pull-up [2]	R_{PU}	4	10	-	kΩ
Filter resistor (low-pass)	R_{LP}	1	15	100	kΩ
Filter capcitor (low-pass)	C_{LP}	10	10	100	nF

[1] Optional component, if EMC optimization requires improved susceptibility levels due to long wiring. Impedance shall be compatible to pull-down or pull-up used at receiver to avoid unwanted signal attenuation.
[2] To indicate a Hi-Z state at the analog output AOUT, e.g. in case of an internal diagnosis error, either a pull-down or pull-up can be used to pull the signal out of the regular voltage range (to GND or VDD).

8 Package Reference

The E524.73 is available in a Pb free, RoHs compliant, 8-pin SO plastic package with footprint according to JEDEC MO-012-F, variant AA. The package is classified to Moisture Sensitivity Level 3 (MSL 3) according to JEDEC J-STD-020E with a soldering peak temperature of 260°C.
Note: Thermal resistance junction to ambient $R_{th,ja}$ is 160 °C/W, based on JEDEC standard JESD-51.

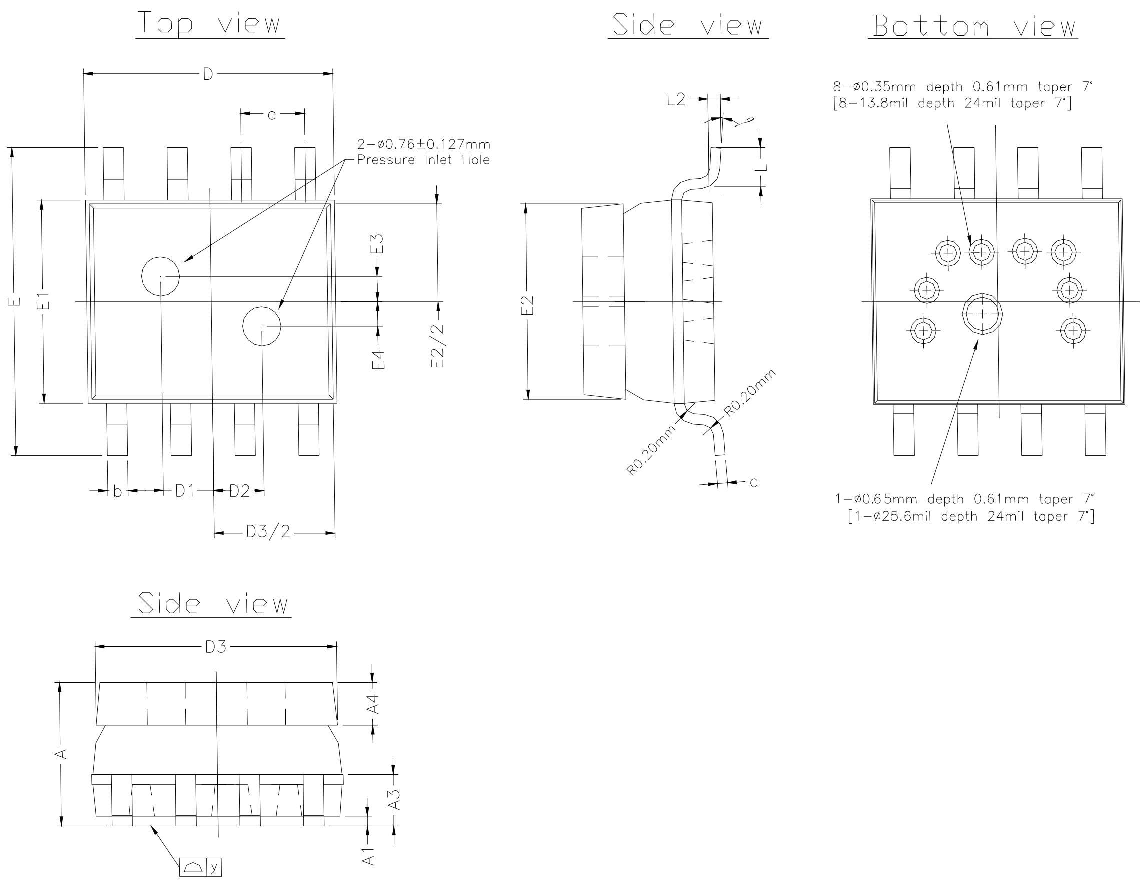


Figure 8-1: Package Outline

Note: Contact factory for specific location and type of pin 1 identification.

Table 8-1: Package Characteristics

Description	***Symbol***		***mm***	
		min	**typ**	**max**
Package height	A		2.79	
Stand off	A1		0.19	
Width of terminal leads	b		0.41	
Thickness of terminal leads	c		0.20 Ref	
Length of terminal for soldering to substrate	L		0.76	
Angle of lead mounting area	Θ [°]	0	-	8
Lead pitch	e		1.27 BSC	
Package length	D		4.95	
Package total width	E		6.00	

Description	Symbol		mm	
Package body width	E1		3.95	
Thickness of the lid	A4		0.83 Ref	
Length of lid	D3		4.80	
Width of lid	E2		3.80	
Off center position, longitudinal, inlet hole	D1 / D2		1.00	
Off center position, lateral, inlet hole	E3 / E4		0.49	

9 General

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Table 10-1: Contact Information

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